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STUDIES ON HYDRAULIC ENVIRONMENTS IN THE KHUNG KRABEN BAY, EASTERN THAILAND

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タイ国東部のクンクラベン湾における水理環境に関する研究

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タイ国沿岸汽水帯の開発と保全に関する基礎的研究が1983年12月に，タイ国と日本との共同研究グループによって実施された。

本研究はタイ国の東部に位置するクンクラベン湾における水理学的な特性に関する現地調査とその電算機シミュレーションに関するものである。シミュレーションの現地との相似性は現場データによって検証され，湾内海水流動のパターンが解明され，それにもとづいて，湾の海水交流量が評価された。

すなわち，湾口からの流入量をQ_e，低潮時水容量をV_1とすると，海水の交流率Q_e / V_1が，24時間当り，6.0となることを示した。

A series of field surveys on the development and conservation in the coastal brackish zone of Thailand were carried out by the Thai-Japanese Joint Research Project Group in December, 1983.

This is the report on the results of investigation and simulation of the hydraulic characteristics of the Khung Kraben Bay located in the eastern Thailand.

The simulation techniques on patterns of sea water flow were checked on the basis of field data observed in the bay. Changes in discharge and water volume were evaluated.

It was found that if the volume of inflow from the mouth of the bay is Q_e and the water volume at L.W. is V_1, then the exchange rate of sea water, Q_e / V_1 is 6.0 in 1/24 hrs.

Introduction

The second field survey on the development and conservation in the coastal brackish zone of Thailand was carried out by the Thai-Japanese Joint Research Project Group in December, 1983. The location investigated was the Khung Kraben Bay near Chantaburi, which is surrounded by a mangrove forest.

The main target to be pursued was an assessment of the possibilities for fisheries development in the Khung Kraben Bay. We took partial charge of a series of ecological studies by carrying out the investigations on hydraulic characteristics, water quality and bottom-sediment properties in the bay.

We report here on the results of investigation and simulation on the hydraulic characteristics in the bay.

Method

1. Field observation

During the period from Dec. 9 to 23, 1983, observations were carried out in Ao Khung Kraban, located in eastern Thailand. At each station shown in Fig.1, current velocity, water temperature and salinity were measured at 1.5 m below the surface. Flow patterns were also investigated by noting the movements of drifters over a given time in the bay. Measurement of water level was made at the mouth (Stn.X).

Main instruments used were a depth/temperature meter (Tecna Elecrro Co.), a portable water current meter with compass (*MODEL 201*, Marsh & Mcbiney Co.), a salinometer (SCT, YSI-33, Yellow Springs Inst. Co.) and a portable recorder (TYPE 3057, Yokogawa Electric Works Co.).

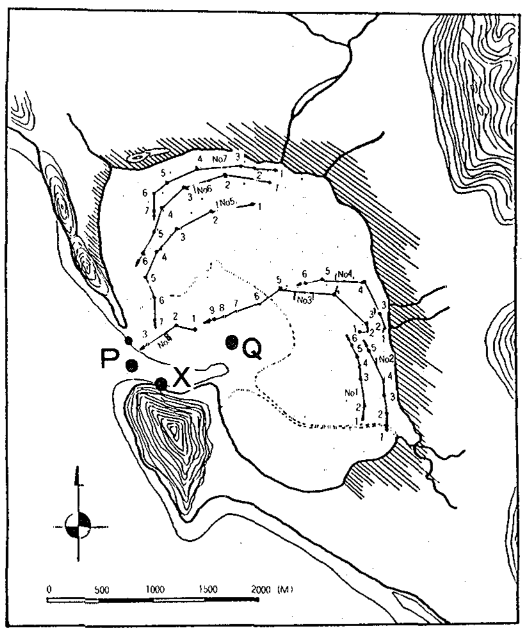


Fig.1 Observed trajectories of drifters.

Table. 1 Movements of drifters with time at ebb tide, Dec. 20-21, 1983. (See Fig. 1)

Drifter	1	2	3	4	5	6	7	8	9	
No. 1	h m 1120	1216	1358	1456	1552	1610				Dec,20,1983
No. 2	h m 1115	1215	1358	1456	1555					
No. 3	h m 1035	1053	1202	1352	1435	1535	1617	1706	1730	
No. 4	h m 1030	1107	1157	1352	1430	1530				
No. 5	h m 1130	1245	1332	1510	1608	1645	1725			Dec,21,1983
No. 6	h m 1125	1220	1350	1515	1605	1652				
No. 7	h m 1123	1125	1220	1340	1520	1600	1655			
No. 8	h m 1045	1155	1310							

2. Numerical simulation

The equations for horizontal motion of homogeneous fluid, averaged vertically and neglecting the convective term and the equation for continuity are formulated as follows :

$$\frac{\partial M}{\partial t} = -\left(\frac{\gamma^2}{h+\zeta}\sqrt{U^2+V^2}\right) M + fN - g(h+\zeta)\frac{\partial \zeta}{\partial x} + A_1\left(\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2}\right) \qquad (1)$$

$$\frac{\partial N}{\partial t} = -\left(\frac{\gamma^2}{h+\zeta}\sqrt{U^2+V^2}\right) N - fM - g(h+\zeta)\frac{\partial \zeta}{\partial y} + A_1\left(\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2}\right) \qquad (1)'$$

$$\frac{\partial \zeta}{\partial t} = -\left(\frac{\partial M}{\partial x} + \frac{\partial N}{\partial y}\right) \qquad (2)$$

where t is the time, ζ the water level displacement of the free surface from its mean level, (x, y) the horizontal cartesian coordinate, and (U, V) the horizontal component of velocity in the (x, y) direction. A_1 is the coefficient of horizontal eddy viscosity, γ the coefficient of bottom friction, f the Coriolis parameter and g the acceleration due to gravity, respectively.

(M,N) is defined as follows:

$$M = \int_{-\zeta}^{h} u dz = (h+\zeta)U \qquad (3)$$

$$N = \int_{-\zeta}^{h} v dz = (h+\zeta)V \qquad (3)'$$

where (u,v) is the velocity in the (x,y) direction at z, h the local mean water depth, and z the depth from the mean water-level, respectively.

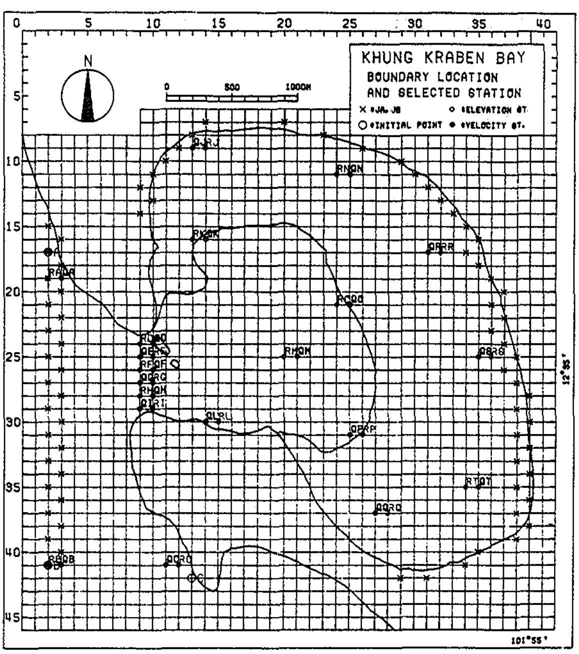


Fig.2 Analysis area for the finite-difference method with square meshes.

Table. 2 The parameters related to the computer simulation.

Discription	Unit	Symbol	Value
time interval	sec	Δt	14
grid interval	cm	Δs	10000
acceleration of gravity	cm/sec	g	980
horizontal eddy viscosity	cm²/sec	A_1	6840
bottom friction		γ	0.0052
Coriolis parameter	1/sec	f	0.00003

In addition to these equations, it is necessary to prescribe initial data and boundary data to have a completly formulated problem with difinitely determined solution. As initial data we must have, as is to be expected, the values of stage and the velocity at some instant of time chosen as initial time at which calculation is to begin. Boundary data are required at the mouth of the bay under consideration.

These equations were solved by a finite-difference method with horizontal square meshes (Fig.2). The computer program presented by T. UENO (1971)[1] was modified for use in the present study. Various parameters related to the computer simulation are shown in Table.1.

Using these numerical solutions obtained with the aid of a high speed digital computer, the Lagrangian movements of a certain mass of water are estimated by use of the following equations :

$$x(t) = \int_0^t U dt \tag{4}$$

$$y(t) = \int_0^t V dt \tag{4'}$$

where $(x(t), y(t))$ is the distance traveled from the origin.

In Eq. (4) (U, V) can be obtained by solving numerically Eqs. (1) and (2). But the drifters under consideration do not always stay at any particular time on the grid point possessing the velocity $(U_{i,j}, V_{i,j})$. Therefore, practical formulations of Eq. (4) may be rewritten for the computation as follows[2] :

$$X_k^{n+1} = X_k^n + U_k \cdot \Delta t \tag{5}$$

$$Y_k^{n+1} = Y_k^n + V_k \cdot \Delta t \tag{5'}$$

where

X_k^n, Y_k^n : the horizontal distance traveled from the origin at the end of each time frame (n). Here, n = 0, 1, 2, 3, ………

Δt : the time frame

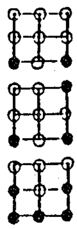
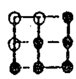
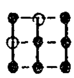
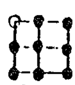
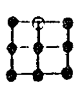
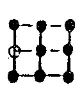
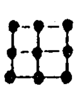
U_k, V_k : the horizontal velocity at each poisition (h, l) with reference to grid points (i, j)

Using the velocity $(U_{i,j}, V_{i,j})$ at the (i,j) grid point for the tidal currents simulation, the velocity (U_k, V_k) at any place is represented on the basis of Taylor's theorem as follows :

$$\begin{aligned} U_k \approx U_{i,j} &+ \frac{h}{2\cdot\Delta s}(U_{i+1,j} - U_{i-1,j}) + \frac{l}{2\cdot\Delta s}(U_{i,j+1} - U_{i,j-1}) \\ &+ \frac{1}{2}\left[\left(\frac{h}{\Delta s}\right)^2 \cdot (U_{i+1,j} + U_{i-1,j} - 2\cdot U_{i,j}) + \left(\frac{l}{\Delta s}\right)^2 \cdot (U_{i,j+1} + U_{i,j+1} - 2\cdot U_{i,j}) \right. \\ &+ \left. \frac{1}{2}\left(\frac{l\cdot h}{\Delta s^2}\right) \cdot (U_{i+1,j+1} - U_{i-1,j+1} + U_{i-1,j-1} - U_{i+1,j-1}) \right] \end{aligned} \tag{6}$$

$$\begin{aligned} V_k \approx V_{i,j} &+ \frac{h}{2\cdot\Delta s}(V_{i+1,j} - V_{i-1,j}) + \frac{l}{2\cdot\Delta s}(V_{i,j+1} - V_{i,j-1}) \\ &+ \frac{1}{2}\left[\left(\frac{h}{\Delta s}\right)^2 \cdot (V_{i+1,j} + V_{i-1,j} - 2\cdot V_{i,j}) + \left(\frac{l}{\Delta s}\right)^2 \cdot (V_{i,j+1} + V_{i,j+1} - 2\cdot V_{i,j}) \right. \\ &+ \left. \frac{1}{2}\left(\frac{l\cdot h}{\Delta s^2}\right) \cdot (V_{i+1,j+1} - V_{i-1,j+1} + V_{i-1,j-1} - V_{i+1,j-1}) \right] \end{aligned} \tag{6'}$$

In applying Eq. (5), it is necessary to give the coastal line boundaries. In this paper, seven types of boundaries are assigned as shown in Fig.3.

(1)  × 4*1, × 4, × 4	$u_k = 0$ $v_k = 0$
(2)  × 4	$u_k = u_5$ $v_k = v_5$
(3)  × 4	$u_k = u_5 + \frac{1}{2}(\frac{1}{2}(\frac{h}{DX})(\frac{l}{DY})(u_9 - u_7 + u_1 - u_3))$ $v_k =$ 〃
(4)  × 4	$u_k = u_5 + \frac{h}{2DX}(u_6 - u_4) + \frac{l}{2DY}(u_8 - u_2) + \frac{1}{2}((\frac{h}{DX})^2(u_6 + u_4 - 2u_5)$ $+ (\frac{l}{DY})^2(u_2 + u_8 - 2u_5))$ $v_k =$ 〃
(5)  × 2*2	$u_k = u_5 + \frac{h}{2DX}(u_6 - u_4) + \frac{1}{2}((\frac{h}{DX})^2(u_6 + u_4 - 2u_5)$ $+ (\frac{h}{DX})(\frac{l}{DY})(u_9 - u_7 + u_1 - u_3))$ $v_k =$ 〃
(6)  × 2	$u_k = u_5 + \frac{l}{2DY}(u_8 - u_2) + \frac{1}{2}((\frac{l}{DY})^2(u_2 + u_8 - 2u_5)$ $+ \frac{1}{2}(\frac{h}{DX})(\frac{l}{DY})(u_9 - u_7 + u_1 - u_3))$ $v_k =$ 〃
(7) 	$u_k = u_5 + \frac{h}{2DX}(u_6 - u_4) + \frac{l}{2DY}(u_8 - u_2)$ $+ \frac{1}{2}((\frac{h}{DX})^2(u_6 + u_4 - 2u_5) + (\frac{l}{DY})^2(u_2 + u_8 - 2u_5)$ $+ \frac{1}{2}(\frac{h}{DX})(\frac{l}{DY})(u_9 - u_7 + u_1 - u_3))$ $v_k =$ 〃

● : sea
○ : land

Fig.3 Boundary geometries used in drifter trajectories.

Result and discussion

The results of the observations are shown in Figs. 1 and 4-6. Fig.1 shows the Lagrangian movements of the particular water mass. From this figure, the circulation pattern in the bay is seen generally counter-clockwise at ebb tide. The motion of sea water in the bay was almost entirely controlled by the inflow from the mouth of the bay, since inflow from the local canals was quite small.

The water levels were measured at Stn. X, Dec. 11-12, 18-19, 20, 21, and 22, 1983 (Fig.4). As shown in Fig.4, the tide was regular diurnal at Stn. X. The difference in water levels between successive high and low waters was 128.7 cm. at spring tide in Laem Sing (ROYAL THAI NAVY, 1983). Tide currents, salinity and water temperature were measured at Stn. X, Q and P. The results are shown in Fig.5 and Fig.6. The maximum value of velocity was 41.0 cm/sec at ebb tide, Dec. 22, 1983. The salinities and temperatures were 30.0— 33.1 ‰ and 25.5 — 29.0°C at Stn. X, 28.8 —31.7 ‰ and 26.1 — 27.5 ℃ at Stn. P, and 32.9 — 29.0 ‰ and 27.3 — 28.0 °C at Stn.Q.

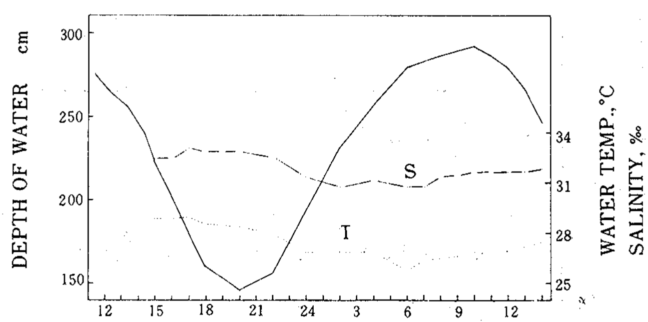


Fig.4 Variations in water temperature and salinity at depth 1.5 m below the sea surface, and tide curve. Measured at Stn. X, Dec. 18–19, 1983.

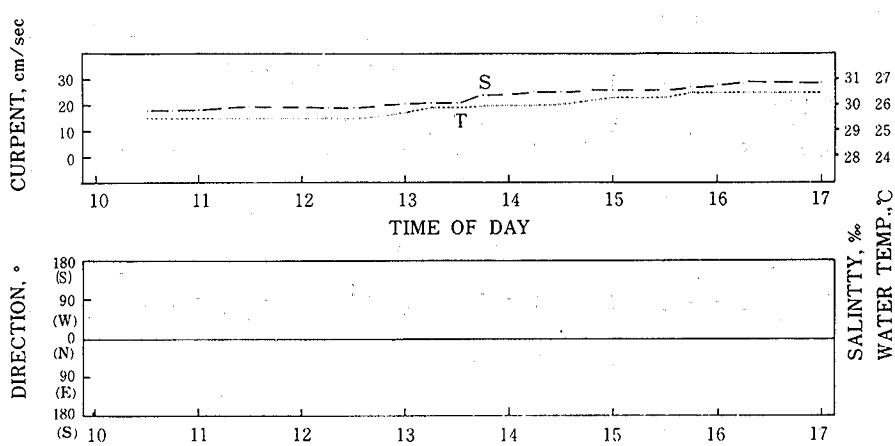


Fig.5 Current speed and direction at depth 1.5 m below the surface. Variations in water temperature and salinity at depth 1.5 m below the sea surface. Measured at Stn. X, Dec. 13, 1983.

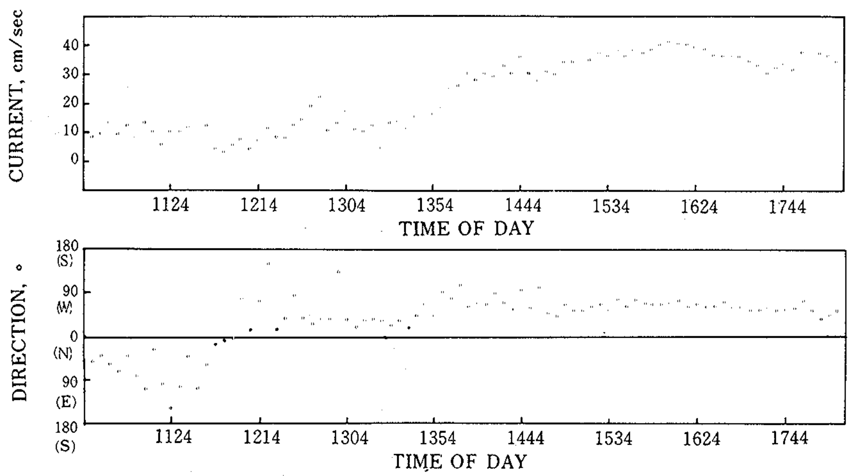


Fig.6 Current speed and direction at depth 1.5 m below the sea surface. Measured at Stn. P, Dec. 22, 1983.

Based on the observed data, the distributions of tidal currents in the bay, which are calculated with the aid of a digital high speed computer, are shown in Fig.7. Fig.8 shows variations in tidal current and tide level over a period of time in some selected positions in the bay.

Using the distributions of currents obtained by the digital computer simulation, Lagrangian movement of water mass over the tidal cycle was checked as shown in Fig.9.

It can bc seen that the drifter trajectories obtained by field observations (Fig.1) were essentially similar to those computed, from a macroscopic standpoint.

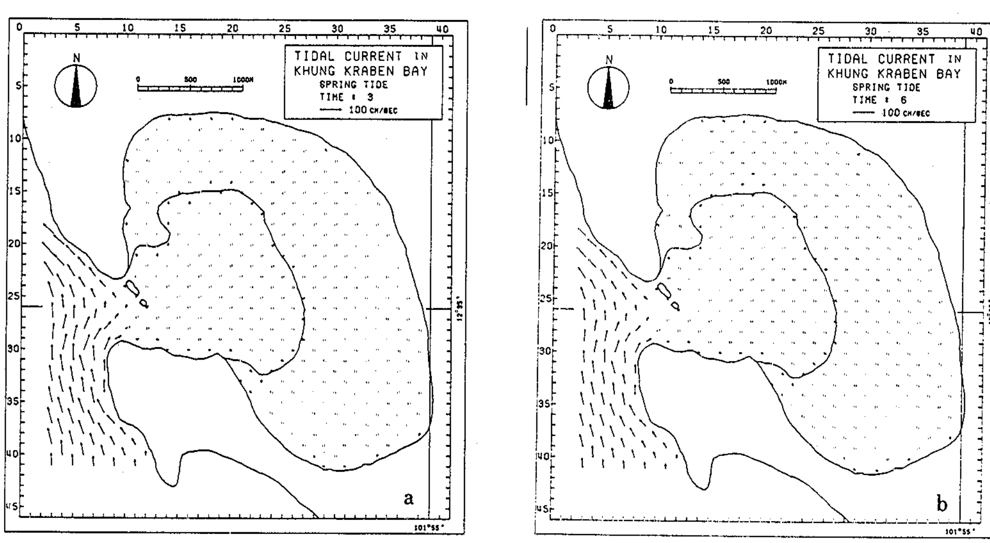


Fig.7.a Distribution of tidal curents during flood tide ; 4 hours before high tide.

Fig.7.b Distribution of tidal currents during ebb tide ; 1 hour before high tide.

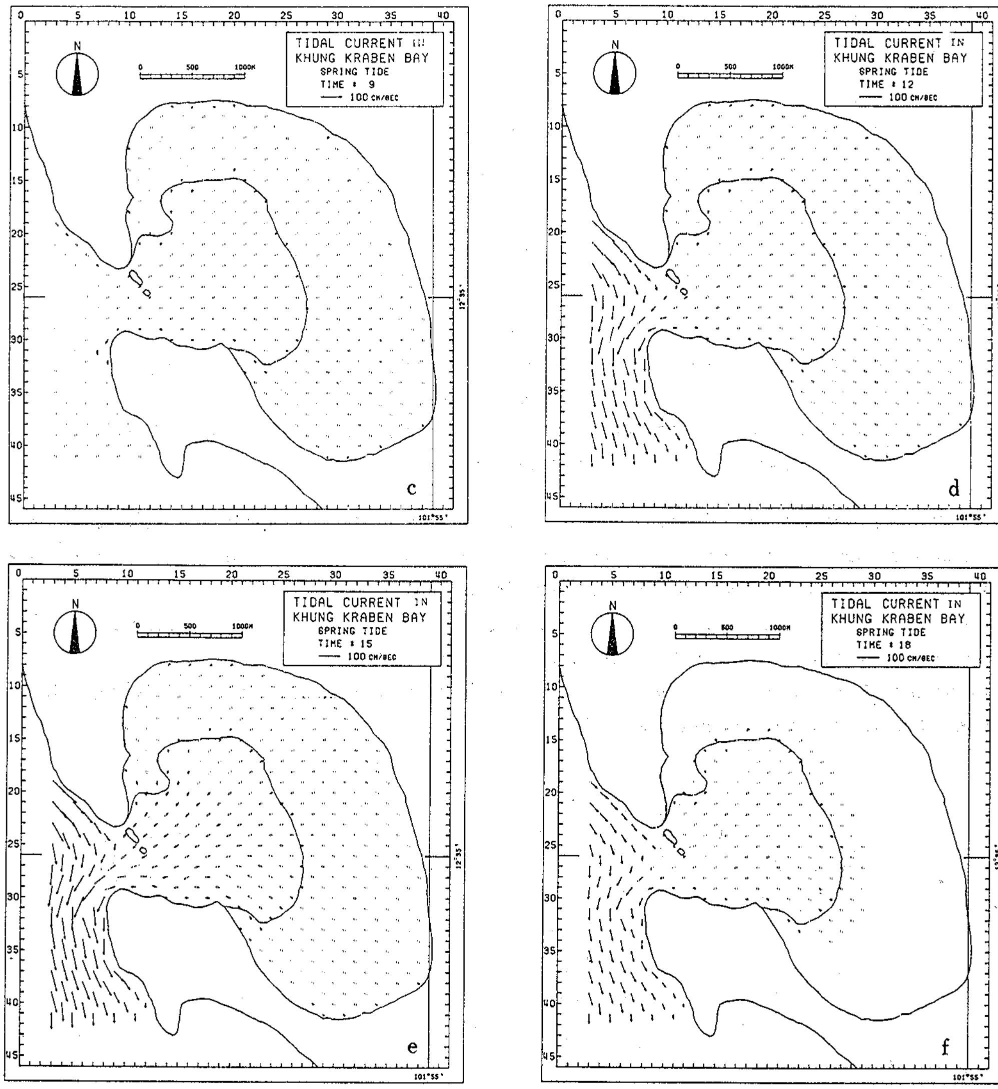
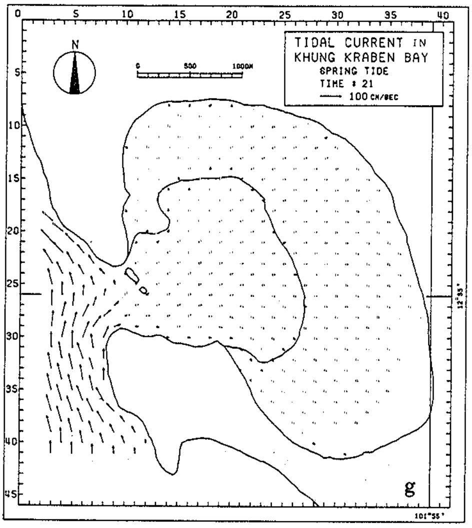


Fig.7.c Distribution of tidal currents during ebb tide ; 2 hours after high tide.

Fig.7.d Distribution of tidal currents during flood tide ; 5 hours after high tide.

Fig.7.e Distribution of tidal currents during ebb tide ; 4 hours before low tide.

Fig.7.f Distribution of tidal currents during ebb tide ; 1 hour before low tide.



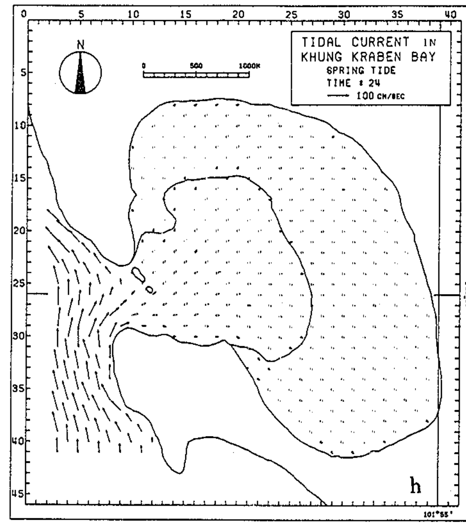


Fig.7.g Distribution of tidal currents during flood tide ; 2 hours after low tide.

Fig.7.h Distribution of tidal currents during flood tide ; 5 hours after low tide.

Once the tidal current and the tidal level have been coded for a computer, it becomes possible to solve all sorts of hydraulic problem quickly. In the present study, changes in discharge and water volume were evaluated. The hydraulic characteristics are summarized as shown in Fig. 10 and Table.3.

It may be found from Table 3 that as the volume of inflow from the mouth of the bay is Q_e and water volume at L.W. is V_1, the exchange rate of sea water Q_e/V_1 is 6.0/24 hrs.. This means that 86 % of the volume of the bay water at low water is replaced with open sea water, in one tide cycle.

Table 3 Hydraulic characteristics in Ao Khung Kraben near Chantaburi.

Water volume, m^3		V_h/V_1	Volume of inflow Q_e $m^3/24hr$	Volume of outflow Q_o $m^3/24hr$	Exchange rate Q_e/V_1 1/24hr	Remarks
L. W. V_1	H. W. V_h					
22.6×10^5	120.0×10^5	5.3	130×10^5	135×10^5	5.9	cycle 1

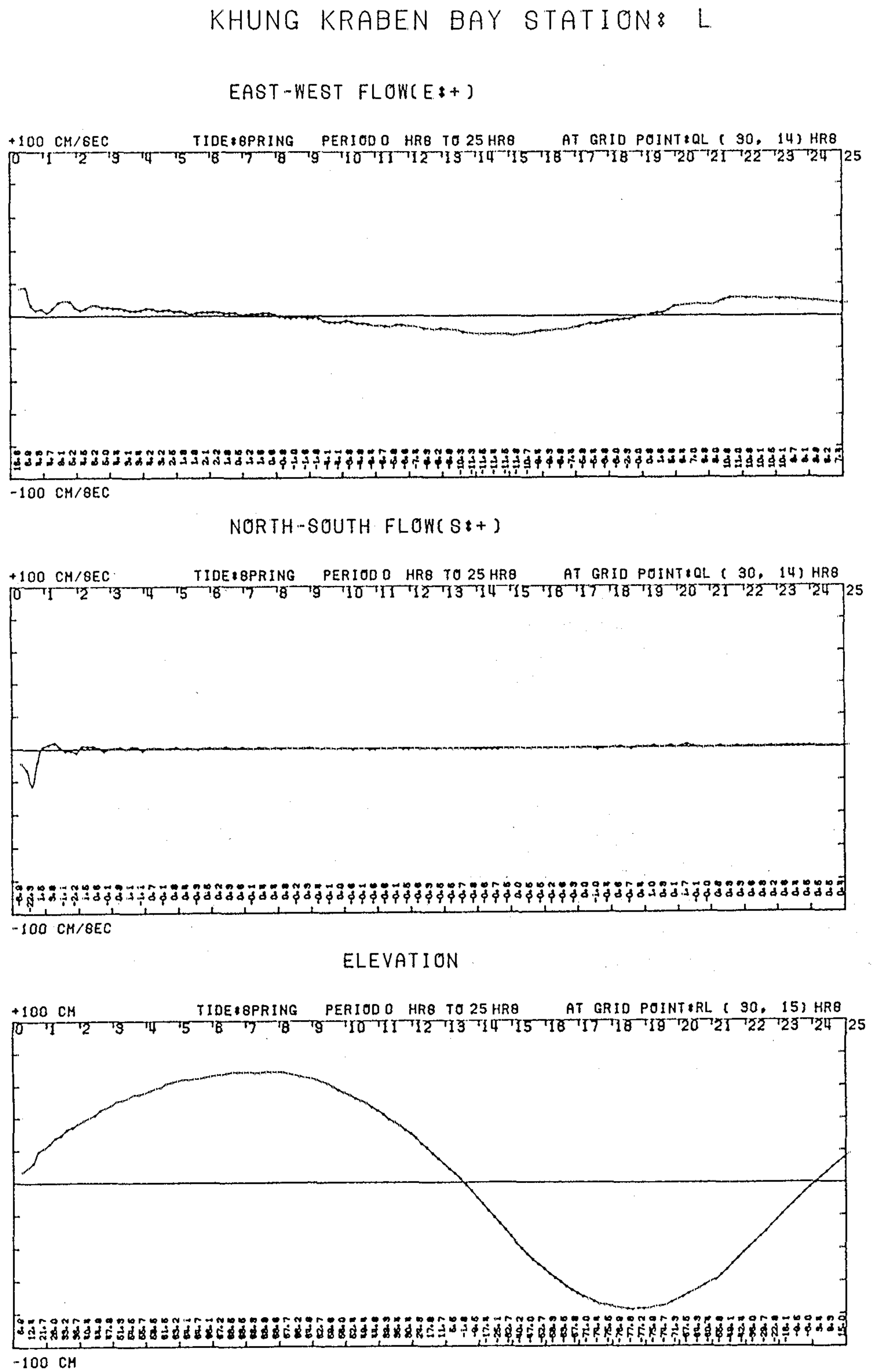


Fig.8 Changes in tidal current and tide curve with time at L.

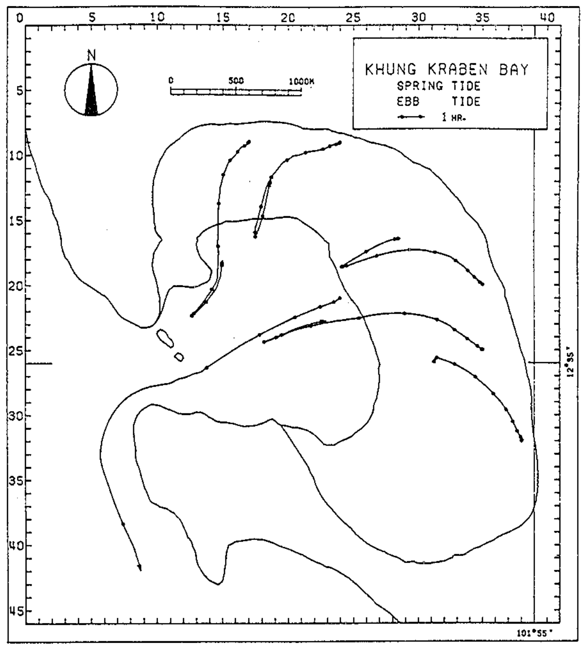


Fig.9 Computed drifter (water mass) trajectories.

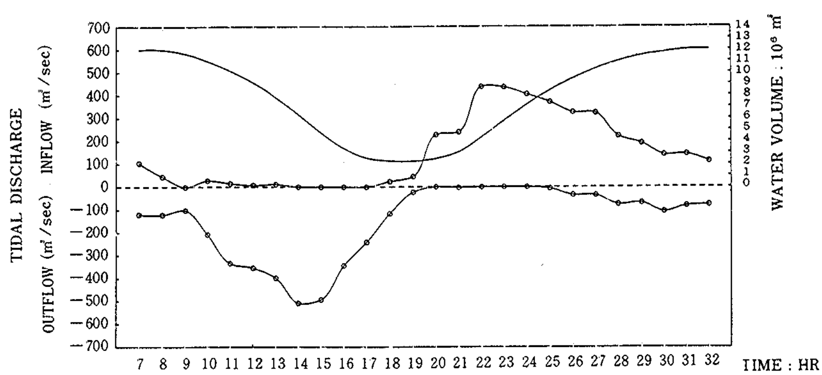


Fig.10 Variations in tidal discharge and water volume in the Khung Kraben Bay.

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